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Investigation of hydroabrasive resistance of internal anti-corrosion coatings used in the oil and gas industry

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Abstract. Anti-corrosion coatings are commonly used in the oil and gas industry to protect the inner surface of pipelines. Most of coatings have a polymer base and can effectively prevent the negative impact of the transported fluid. Existing standards allow to evaluate the quality of coatings and their durability in the anticipated operating conditions. The evaluation of the abrasive resistance of coatings usually limited to comparative tests on a Taber abraser. This paper presents the results of hydroabrasive resistance study of coatings using nonstandard technique. Comparative test results of various polymer (FBE), thermally sprayed coating and silicate coatings are obtained. The ways of modifying test method are proposed.

1. Introduction

In the oil and gas industry corrosion is one of the main problems. A large number of pipelines have been in operation for more than 30 years, which leads to an increased number of incidents related to a corrosion damage [1]. To reduce the number of incidents leading to economic and environmental losses, as well as to increase the operating life, various methods of corrosion protection are developed and applied. The main ones include inhibition and use of pipes with an internal anti-corrosion coating [2]. The use of inhibitors is an effective method of corrosion protection, although has several drawbacks such as the limited use in environments with a high concentration of abrasive particles and the presence of fixed costs throughout the entire period of operation. The use of pipes with an internal coating is one of the most effective methods of dealing with corrosion damage. The most common use is polymer-based coatings, such as fusion bonded epoxy (FBE). Such coatings protect the inner surface of the pipe from the influence of the transported medium, and due to the low surface roughness, increase the productivity of the pipeline [3].

Polymer coatings have been used for a long time, but in recent years there has been an increased interest in such products in the oil industry. The result of a large number of studies and the accumulation of experimental data led to the creation of the regulatory document GOST R 58346-2019 “Steel pipes and fittings for the oil industry. Protective coatings on the inner surface. General technical requirements” [4]. This document describes the certification procedure for internal anti-corrosion polymer coatings for use in oilfield pipelines and tubing. In the standard, test methods are collected and streamlined that allow to evaluate most of the properties of coatings and determine the possibility of their use in the selected conditions.

The least attention is paid to hydroabrasive wear of coatings, while the effect of solid mechanical particles in the fluid flow is one of the main reasons for the failure of oilfield equipment [5, 6, 7]. Material wear occurs as a result of cutting micro- particles from the surface or detachment of individual particles as a result of contact fatigue. The rate of polymer degradation under conditions of hydroabrasive wear is affected by the flow rate, the chemical composition of the operating medium, the concentration of abrasive, the temperature of the medium, the angle of interaction, coating hardness, elastic modulus, coating thickness, etc. [8].

The lack of standard methods for assessing hydroabrasive wear is due to the complexity of modeling wear processes. As a standard method for assessing the abrasion resistance of a coating, ASTM D4060-14 “Standard Test Method for Testing Organic Coatings for Abrasion Resistance Using the Taber Instrument” is generally used [9]. This method is comparative and does not simulate real operational (field) impacts, the inadmissibility of its use for evaluation was already written in [10], since the basis of this method is the process of dry friction, and not hydroabrasive wear, which is realized under operating conditions.

Therefore, to assess the hydroabrasive wear of oilfield anticorrosive coatings, a technique was applied based on the corrosion-mechanical test method to evaluate the metal of pipes [11] at the bench test, which was improved and used to assess the resistance of coatings.

The aim of the work is a comparative assessment of hydroabrasive wear of anticorrosive coatings (polymer, silicate-enamel, thermally sprayed Al-Mg) used to protect oilfield pipelines and oilfield equipment.

2. Experimental

The tests were carried out on a facility that allows testing materials in aqueous media with the addition of abrasive material. Hydroabrasive action occurs due to the introduction of abrasive into the solution in the form of silica sand with a concentration of 1.5% silica sand, the fraction size is 0.5 - 1.0 mm. A uniform distribution of abrasive particles in the solution is achieved due to the constant circulation of the test medium in the system. The flow rate is 8.5 m^3 / hour. The temperature of the test solution is 30 ± 5 ° C. The test duration is 8 hours. If the coating is worn to the substrate in less time, the test was terminated. Figure 1 shows the installation diagram and its general view in the assembly.

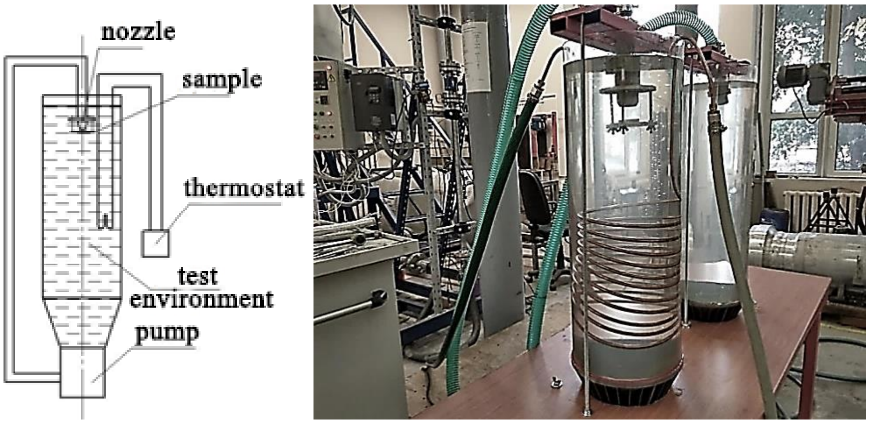


Figure 1. The scheme of test equipment.

Three samples were prepared for testing, with a size of 30 * 30 mm of each type of coating. The sample was installed at the angle of 95 ° relative to the direction of flow. Samples were weighed on an analytical balance with an accuracy of 0.0001 g before and after the tests, and also before the tests, the coating thickness was measured with an accuracy of 1 μm. Also, the wear time of the coating to the substrate was estimated.

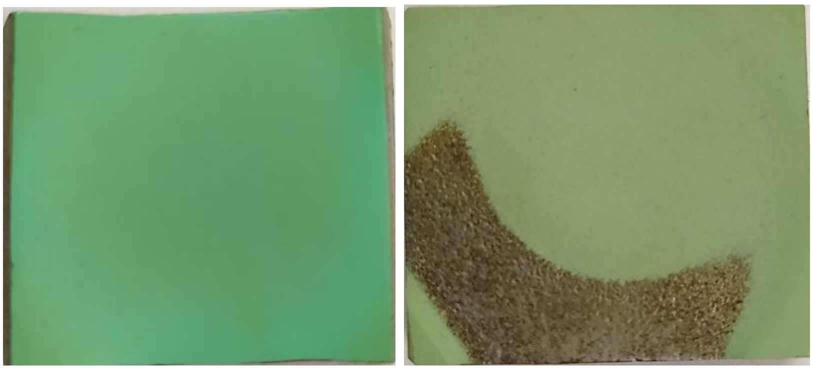
3. Test results

The results of the tests for resistance to hydro abrasive wear are shown in table 1.

Table 1. Hydro Abrasion Test Results

Type of coating	№	Mass before, g	Mass after g r	Mass loss, g	Average mass, r	Thickness, μm	Time, h	Note
Thermally sprayed	1	39,97	39.70	0.27	0.27	105	2	Heavy wear
	2	42.91	42.64	0.27		101	2	
	3	41.56	41.30	0.26		109	2	
Epoxy 1-2	1	44.52	44.40	0.12	0.10	332	5	To substrate
	2	48.42	48.32	0.10		315	5	
	3	47.95	47.88	0.08		335	5	
Epoxy 2-1	1	36.09	35.99	0.10	0.10	502	8	No wear
	2	36.33	36.22	0.11		504	8	
	3	33.31	33.23	0.08		580	8	
Epoxy 2-2	1	40.80	40.55	0.26	0.28	540	8	To substrate
	2	43.82	43.51	0.31		521	8	
	3	41.57	41.29	0.28		563	8	
Epoxy Phenolic	1	57.93	57.49	0.44	0.42	495	4	Heavy wear
	2	55.32	54.91	0.41		498	4	
	3	54.63	54.21	0.42		492	4	
Silicate	1	36.27	35.80	0.46	0.5	1.28	4	Heavy wear
	2	31.40	30.83	0.58		1.83	4	
	3	30.37	29.90	0.47		1.54	4	

As a result of the tests. it was revealed that there were no patterns - the greater the thickness. the lower the wear out. Figure 2 shows a comparison of the state the samples surface after testing.



a) b)

Figure 2 - Samples after testing: a) epoxy №6-1. b) epoxy-phenolic № 8-1.

The coating marked 2-1 is a powder coating with a declared operating temperature of +110 ° C and a thickness of ≈ 500 μm. After 8 hours of testing. the coating did not lose its continuity. Epoxy phenolic coating with a maximum operating temperature of +60 ° C and a thickness of ≈ 500 μm was tested. After 4 hours of testing. the continuity of the coating was broken. Samples of epoxy phenolic coatings also have higher rates of hydro abrasive wear compared to powder polymer coatings of similar thickness. Such results can be explained by the lower hardness of the epoxy phenolic coating.

Figure 3 shows samples with a thermally sprayed coating and a silicate coating after testing. The lowest characteristics of resistance to hydroabrasive were determined for a thermally sprayed coating based on Al-Mg. Fig. 3. a. it wore to the substrate in 2 hours of testing. A high wear rate could be attributed to a roughness and a thickness of ≈ 100 μm. which is 3 to 10 times less than other coatings studied.

a) b)

Figure 3 - Samples after testing: a) metallization coating. b) silicate coating.

Silicate-enamel coating. despite a considerable thickness (more than 1 mm). was worn down to the substrate during 4 hours of testing. which may be due to the known fragility of coatings of this type. It is evident that wear occurs more likely to be chipped. and not due to uniform wear (figure 3. b).
Thus. comparative tests of various types of coatings were carried out. High test results were obtained when testing samples of one coating.

4.Conclusions

1. The technique used to assess the hydroabrasion resistance allows a comparative rapid assessment for choosing of various types of coatings both on plates and on samples from pipe segments.
2. The proposed method allows to assess the degradation of the hydro abrasive resistance of the coating after other laboratory tests.
3. According to the results of the tests. the epoxy coating turned out to be more resistant in comparison with the epoxy phenolic coating.
4. The thermally arc sprayed Al-Mg coating showed low hydroabrasive resistance. which is probably due to its thickness and application features.
5. The silicate coating showed low hydroabrasive resistance due to its brittleness.
6. Verification of the obtained values in experimental field trials would allow us to assess the degree of applicability of the methodology.

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